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Application of Stereoscopic (3-D) Slides to Roof and Rib Hazard Recognition Training

By Edward A. Barrett, William J. Wiehagen,
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UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	mm	millimeter
in	inch	pct	percent

APPLICATION OF STEREOSCOPIC (3-D) SLIDES TO ROOF AND RIB HAZARD RECOGNITION TRAINING

By Edward A. Barrett,[1] William J. Wiehagen,[2] and Robert H. Peters[3]

ABSTRACT

The ability to recognize visual cues commonly associated with roof and rib hazards is fundamental to the prevention of groundfall accidents. The perceptual skills that miners possess to visually search and assess hazardous ground conditions differ considerably. This U.S. Bureau of Mines report summarizes recent investigations on the use of stereoscopic (3-D) slides as a training aid for improving the ability of miners to recognize the various geologic and mining-induced irregularities that cause groundfalls. The feasibility of using 3-D slides for training and their effectiveness for representing roof and rib hazard conditions are discussed. Information is presented on equipment and procedures for creating a 3-D slide program that can be updated by mine trainers. Recommendations are made on selection of 3-D equipment and on the use of 3-D slides for training miners to recognize roof and rib hazards.

[1]Mining engineer.
[2]Supervisory industrial engineer.
[3]Research psychologist.
Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

Many factors influence the likelihood of groundfall accidents. Some, such as geological factors that establish the inherent stability of the roof and rib and hidden irregularities that become exposed as mining advances, lie beyond the control of the underground worker. However, miners can maintain some level of command over these factors and their effect on groundfall accidents by having the ability to recognize and correct potential hazards. *Recognition* of hazards means that the worker perceives the warning associated with the problem, recognizes the warning for what it actually represents, and assesses the risk involved. *Correction* of hazards includes actions such as avoiding the problem area, seeking assistance in addressing the problem, or actually making physical changes. Each of these actions constitutes an attempt on the part of the miner to deal with, or correct, the problem. It is essential for their individual safety that all workers be capable of recognizing roof and rib hazards. Clearly, ground hazard conditions affect everyone who works underground, regardless of specific job responsibilities. The potential for danger exists everywhere; therefore, all miners have a need to be competent in the detection of roof and rib hazards as they perform tasks underground or simply commute to and from work stations.

To illustrate, in a review of recent Mine Safety and Health Administration (MSHA) accident and fatality reports, it was noted that groundfall accidents may have been prevented in some cases had workers been able to detect the presence of hazardous features and properly assess the risk. For example, consider the following conclusions filed by MSHA inspectors following two separate investigations: "the accident occurred when a piece of undetected roof (horseback formation) fell from between the roof bolts causing fatal injuries to the victim" and "the contributing factor to the accident and resultant fatality was the presence of an undetected kettlebottom near the face of No. 5 entry." Of course, it is not possible to ascertain the visual capabilities of the persons involved in these incidents with any reasonable degree of accuracy. The visual information available to the miners at the moment of the accident may have been occluded or perhaps the persons did indeed recognize the hazards but failed to assess the degree of danger or simply ignored the hazard. The point is that opportunities exist to improve the perceptual abilities of underground workers and to increase their capacity for making sound judgments about how to deal with perceived dangers.

Further evidence of the need for better training in the identification of groundfall hazards can be found in two recent Bureau studies. The first study investigated the human factors contributing to groundfall accidents in underground coal mines (*1*).[4] This report summarized the views of miners, section supervisors, and mine inspectors regarding what they think should be done to reduce the frequency of injuries sustained in falls of roof and rib. In one portion of the study, 143 miners from nine different underground coal mines were asked to indicate the degree to which each of nine possible strategies would help them avoid rockfall injuries. The following six-point rating scale was used: 1–very small, 2–small, 3–somewhat small, 4–somewhat large, 5–large, 6–very large. The list included strategies such as adding more support to bad areas of roof, better installation of roof bolts, better training in proper methods of supporting the roof, and better training in the identification of roof hazards. Sixty-eight percent of the miners said, to a large or very large degree, that better training in identifying roof hazards would help them avoid rockfall injuries.

The miners were also asked several questions about their experiences with rockfall accidents. Sixty-two percent (88 out of 143) reported having had some type of recent experience with a rockfall. These included rockfalls that resulted in injuries and those that were close enough to startle nearby workers. These data suggest that unplanned rockfalls in underground coal mines are all too frequent events. In such environments, miners need to understand and be familiar with potentially hazardous roof and rib conditions. Moreover, of the 88 incidents reported, 66 occurred within approximately 25 ft of the face and 52 happened within a few minutes after the worker had arrived at the area. This suggests that many rockfall accidents may be avoided if workers would examine the roof, particularly before initiating work in a new area.

The implication here is that in order for hazardous ground conditions to be corrected, the miner must first be capable of identifying the problem and correctly assessing the potential risk. The inability of the worker to visually search, identify, and judge the degree of danger of obvious as well as subtle roof hazards can significantly increase the odds of unplanned, unanticipated roof failures and subsequent accidents.

In the second study, an empirical test was designed to measure the effectiveness of 3-D slides for depicting ground hazards (*2*). One of the research objectives was to determine if underground experience is related to the visual skill level of miners. Results from this portion of the study indicated that in viewing a set of 3-D slides of groundfall hazards a group of experienced miners failed to correctly identify the hazard in approximately 17 pct of the slides. Another group of persons with limited underground working experience failed to correctly identify the hazard in approximately 33 pct of the same set of slides. While ability does improve with experience, these results indicate that miners, even experienced ones, sometimes fail to recognize certain types of potentially dangerous roof and rib conditions. These findings imply a need for improved ability in the perception and recognition of groundfall hazards.

[4]Italic numbers in parentheses refer to items in the list of references at the end of this report.

ACKNOWLEDGMENTS

The authors thank Henry J. Kellner, industrial engineering technician, Pittsburgh Research Center, and Marion B. Molchen, design draftsman, Boeing Services International Inc., for their assistance and cooperation in 3-D equipment design and numerous field evaluation exercises.

GROUND HAZARD RECOGNITION TRAINING

All miners are required by law to receive training in a prescribed array of mine health and safety topics. The ground control portion mandates, as a minimum, a review of the roof or ground control plans in effect at the mine and, for some, instruction on procedures for dealing with ground control problems. At some mines, the training programs include roof and rib hazard recognition or awareness training. Examples of the former may include how to bar down loose roof with a pry bar or how to sound roof. The latter may involve, in addition to the recognition of hazards such as geologic irregularities and loose rock occurrences, learning particular skills and gaining knowledge for determining the proper course of action to pursue and when to take the action.

To determine an appropriate course of action, discrimination of relevant cues is required as well as recall and identification of applicable rules and concepts. The perceptual abilities and skills of the miner are invoked in order to observe these cues. A comprehensive ground control training program would ideally include a combination of these elements; that is, information that is required by law (roof control plan and ground control procedures) and skills training in the recognition of roof and rib hazards. The following scenario, taken from a recent MSHA fatality report, illustrates the need for such a comprehensive ground hazard recognition training program.

On April 2, 1985, a miner helper was killed by a fall of roof while installing temporary support for setting line brattice inby permanent support. The accident involved a 7-ft by 7-ft by 7-in-thick slab of the immediate roof shale. Investigators reported that although the fallen slab was not a true kettlebottom, it was similar in shape. It was nearly circular in plan view and was bounded on one edge by a slickensided surface. One side of the slab coincided with a portion of a flattened, carbonized fossil tree trunk that was oriented parallel to the shale bedding and was approximately 20 in wide. It appeared that the rock separated along the outby (slickensided) edge, along the plant fossil, and along a shale lamina. The rock then sheared along the inby edge near the rib. The investigators concluded that the victim, who had 36 years of mining experience, failed to detect the loose rock condition and placed himself in an unsafe position while advancing the line brattice.

The question naturally arises as to whether the victim could have been trained to a level of skill that would have prevented making the error that led to his death. Theoretically, the answer is yes. However, it is unlikely that simply giving him more of the same kind of training would have sufficed. What could be more effective is the opportunity to practice perceptual and judgmental skills in a training environment designed to simulate, to a high degree of fidelity, ground conditions that a miner needs to learn to recognize.

Traditional visual aids used in mine training classes—films, overhead projections, videos, and slides—are two-dimensional (2-D) models that represent the three-dimensional world. Some trainees, particularly new miners, are unable to form mental images of hazardous ground conditions so that transfer of learning can occur when the person goes underground.

The need for classroom simulations of real conditions has long been recognized in the training industry. Gibson, for instance, suggested that in industrial training there should be devices that would simulate particular dangers while allowing subjects to act safely or unsafely (*3*). One problem with simulations, however, is that they often have an artificiality that is difficult to surmount. This is particularly true with roof and rib hazards. Moreover, as these hazards are represented in 2-D images, they become less authentic looking and quite unlike the real entity. Confounding this simulation problem is the complex mine environment where the visible cues are subtle, constantly changing, and often masked (rock dust, bad viewing angle, limited lighting). Nevertheless, classroom training effectiveness and transfer must depend on instructional materials that physically simulate the real world environment. This is generally true for all types of training and, in particular, for mine roof and rib hazard training because of the nature of inherent hazards and extremely variable conditions.

One attempt to simulate ground hazards in mining was carried out in 1979 by Blignaut who asked subjects to perform motor tasks while simultaneously looking for loose rock in a stope simulator (*4*). Although Blignaut reported that the simulator was viewed as realistic by the participants, such a device would be relatively difficult and quite expensive to build with any degree of fidelity. Blignaut followed this with another attempt to simulate ground hazards that appears to offer more promise to mine safety trainers. This second attempt involved the use of 3-D slides to train underground miners. The results of his study involving South African gold miners suggest that the ability of underground miners to discriminate between dangerous and safe rock conditions can be improved significantly by exposing them to 3-D slides of groundfall hazards.

Although Blignaut's results were encouraging, they failed to provide guidelines for using 3-D slides as training aids to teach hazard recognition skills. Therefore, the Bureau undertook a pilot study to determine the efficacy of using 3-D slides for coal mine ground hazard recognition training.

The first step was to produce a representative set of 3-D slides of hazardous roof and rib conditions typically found in coal mines. A variety of hazardous underground conditions were photographed in 3-D at mines throughout the major coal producing areas of the eastern United States. The slides contained *geologic features*, such as joints, bedding planes, and kettlebottoms; *inadequate support conditions*, such as spalling ribs, loose or hanging bolts, and incorrect bolting patterns; and *loose rock occurrences*, such as overhangs. The second step was a research study to investigate the feasibility of utilizing 3-D slides as a training aid for improving the miner's ability to recognize hazardous roof and rib conditions.

FEASIBILITY OF USING 3-D SLIDES AS A TRAINING AID

Four feasibility issues were investigated: Acceptance of 3-D slides by trainers and trainees, compatibility with current ground control instruction methods, effectiveness of 3-D slides as a training aid, and availability, cost, and reliability of 3-D photographic and projection equipment (*5*). Data were collected using a structured interview guide and two sets of slides, one in 2-D and the other in 3-D, of common, easily recognized ground hazards. The data were obtained from mine managers, company and union officials, Federal and State inspectors, mine safety and training personnel, and miners. The information generated in the first three areas of the investigation was essentially a collection of observations from the respondents based on intuition after viewing the slides in a handheld viewer. This provided data for establishing the face validity of 3-D slides for training. Complete details of this feasibility study are reported in reference 5. A discussion of the segment of the study relating to the effectiveness of 3-D slides from the perspective of mine safety and training personnel follows.

In the study, data were collected on the plausible use of 3-D slides as a training aid for ground control from 47 persons who attended MSHA's 1985 National Mine Instructor's Conference, from 9 MSHA ground control specialists, and from 143 miners working underground. Virtually all of these people agreed that 3-D slides were much better than 2-D slides for portraying critical features of hazardous areas of roof and rib, and that 3-D slides would make an excellent training aid. A portion of the response information offered by those who participated in the conference is outlined here. The opinions of this group are meaningful because (1) group members were or had been directly associated with miners' training and, hence, should be good judges of the effectiveness of 3-D slides as a training aid and (2) they represented the hierarchy of persons in a mining company who could decide if 3-D slides should be added to their training programs.

The conference attendees were asked a series of questions about the effectiveness of 3-D photography and the overall feasibility of using 3-D slides as a mine training aid. Each participant was asked to view eight slides of hazardous roof or rib conditions. Each slide was presented first in the conventional 2-D form, and then in 3-D form.

The first question asked was: "To what extent are 3-D slides more or less effective than conventional (2-D) slides at portraying groundfall hazards?" Responses to this question (table 1) indicated that most participants (93.3 pct) believe that 3-D slides are a great deal more effective than 2-D slides at portraying groundfall hazards, and that a very small percentage (2.2 pct) think they are less effective.

Participants were also asked: "What benefits (if any) would there be to adding 3-D slides illustrating groundfall hazards to your company's safety training programs?" The benefits that were most often listed include

Would provide a more realistic representation of hazards.

Would be more interesting to the trainees.

Would make it easier to teach miners about hazards.

Would increase miners' abilities to recognize hazards.

Would help to generate more discussion.

Participants were then given several statements concerning how most miners would react to the addition of 3-D slides to their mine safety training and asked to circle each statement with which they agreed. Of the sample, 68 pct believed that 3-D slides would improve miners' abilities to detect hazardous conditions; 66 pct thought that miners would enjoy seeing a new and unique type of training slide; 57 pct expected that 3-D slides would elicit more discussion about the hazards portrayed; and 46 pct thought miners would view 3-D slides as an attempt to upgrade their training. Only one person indicated that 3-D slides would have no effect on miner's performance.

TABLE 1. - Effectiveness of 3-D slides in portraying groundfall hazards

Category label	pct
Much more effective than 2-D slides	71.1
More effective than 2-D slides	22.2
Slightly more effective than 2-D slides	4.5
The same as 2-D slides	0
Less effective than 2-D slides	2.2

Finally, participants were asked to suggest other mine training applications for 3-D photography in addition to illustrating groundfall hazards. Specific safety and task training applications noted were new miner orientation, preblasting and postblasting surveys, and accident investigations.

The three most important advantages of 3-D slides over 2-D slides for teaching ground hazard recognition skills indicated by the workshop participants were (1) they illustrate groundfall hazards more realistically, (2) they make it easier to teach this area of training, and (3) they can make ground control training, in general, more interesting for miners. Overall, the feasibility study concluded that it is indeed possible for mine trainers to use 3-D slides of hazardous mine roof and rib conditions as a training aid for teaching the worker to recognize groundfall hazards. Specific concerns noted in this study focused on the question of availability and practicality of existing 3-D photographic equipment. These were addressed in followup Bureau investigations and are presented in a subsequent section of this report.

EFFECTIVENESS OF 3-D SLIDES

There are few references on the utilization of 3-D slides for instructional purposes in the literature, and those specifically reporting on the application of 3-D slides for ground hazard recognition training were limited to the Blignaut study previously reported. To supplement Blignaut's work, a pilot study was conducted to determine the effectiveness of 3-D slides for the recognition of ground hazards.

A field experiment was designed with the primary objective of determining if visual cues associated with ground control hazards are more apparent when represented in 3-D slides than in 2-D slides (*2*). A secondary objective was to determine if underground experience has some effect on the visual skill levels of miners. The experimental strategy adopted for the investigation resulted in a 2 by 2 factorial design (diagrammed below) in which mode of stimulus presentation (3-D or 2-D) was experimentally combined with the level of experience (experienced or inexperienced) of the miner.

	3-D	2-D
Experienced miners		
Inexperienced miners		

The two independent variables, subsequently referred to as the main effects in the experiment, were the type of stimulus material (3-D or 2-D) and the level of experience of the observer (experienced or inexperienced miner). Forty subjects participated in the experiment, 10 in each cell. Twenty miners had underground experience ranging from 2 years to 39 years. The 20 inexperienced subjects were persons with casual and limited underground experience, that is, either students in a mining engineering curriculum or researchers on mining projects. None of the latter had worked underground; however, all were familiar with mining to some degree. Each subject was asked to view a set of 15 slides. The slides were prejudged by experts to be those of relatively common ground hazards. Members of half of each of the two groups (either experienced or inexperienced) were shown the roof and rib hazards using 3-D slides, and the remaining group members were shown identical 2-D slides. After viewing the slides, each subject was asked to respond as follows: (a) describe the hazard, (b) indicate the degree of danger of the hazard (lethal, high, mild, or minimum), and (c) indicate how the hazard can be corrected. Correct responses to each query are shown in the following individual cells.

Describe the Hazard

	3-D	2-D
Experienced	125	96
Inexperienced	101	66

Indicate the Degree of Danger of the Hazard

	3-D	2-D
Experienced	86	64
Inexperienced	93	66

Indicate How the Hazard Can Be Corrected

	3-D	2-D
Experienced	124	73
Inexperienced	97	64

The correct responses given by all 40 subjects to each query were treated using a 2 by 2 analysis of variance (ANOVA) to determine the significance of both main effects–level of experience and mode of stimulus presentation. Complete summary tables for the two-way ANOVA can be found in reference 2. From these data it was concluded that both main effects were statistically significant ($p < 0.01$). In comparison to the group of persons with limited underground experience, the proportion of correct responses was significantly higher among experienced miners. In comparison to the group who viewed the slides in 2-D, the proportion of correct responses was significantly higher among those who viewed the slides in 3-D, both for experienced and for inexperienced miners.

The first of these two findings suggests that significant differences exist between the ability of new versus experienced miners to correctly identify groundfall hazards.

An important footnote to this finding is that, on the average, even the experienced miners failed to correctly identify 2.5 out of 15 hazards. This suggests that better training in recognizing groundfall hazards could benefit experienced miners as well as miners who have little or no underground experience.

The second finding clearly denotes that 3-D slides are more effective for the purposes of illustrating groundfall hazards. Therefore, it can be concluded from this study that 3-D slides are a better medium than 2-D slides for illustrating groundfall hazards for all miners.

3-D PHOTOGRAPHY

ORIGINAL EQUIPMENT

Stereo photography dates back to the mid-19th century with the invention of the stereoscope (stereo viewer) in England by Sir Charles Wheatstone. However, until the introduction of Kodachrome film in 1936, stereo photography had limited appeal and use, other than hobby, due mainly to poor technical quality and inferior equipment. Interest was revived in 1947 with production of the Realist stereo camera; Kodak, Wollensak, Delta, Coronet, TDC, and other manufacturers followed with similar 3-D camera designs (fig. 1).

Stereoscopic cameras are 35-mm slide cameras that have dual, matched objective lenses with mechanically coupled iris diaphragms. They have a normal range of aperature settings, shutter speeds, shoe adapters, and focus adjustments. Any standard color or black and white slide film in the common range of ASA speeds may be used. It should be noted here that these are slide cameras and cannot be used for taking 3-D photographs. A four-lens camera system is required for taking 3-D prints.

Stereoscopic slides can be viewed either on a screen or through handheld devices. The equipment required to project and view 3-D slides on a screen include a 3-D slide projector and polarized 3-D glasses (fig. 2). For this, a special viewing screen must be used that has a lenticular surface. The screen image from a 3-D slide projector is not as clear as that observed in a handheld 3-D viewer (fig. 3). Polarized glasses must be worn to see projected 3-D slides; however, polarized glasses are not required with the handheld viewer.

Stereo slide film is developed in the same manner as other 35-mm film; however, the preparation and mounting of 3-D slides is done by relatively few film processing companies because the work is time-consuming and costly. This, of course, presents a problem, not only with originals, but when duplicate sets of slides are required for training purposes.

Several concerns exist regarding the acquisition and functional capabilities of 3-D cameras and projectors. Perhaps the most critical problem with 3-D cameras is limited availability; they are not currently being manufactured, as commercial production was terminated more than 30 years ago. Reconditioned cameras may, however, be found in some used equipment departments of photographic supply stores. Occasionally, advertisements can be found in photography magazines to purchase 3-D cameras through mail order. Some 3-D cameras have also become collector's items among stereo enthusiastics. Manufacture of 3-D slide projectors also was discontinued many years ago; however, they too can occasionally be found in used equipment departments of camera shops. The available supply of used 3-D projectors is considerably less than that of 3-D cameras because fewer companies manufactured them originally.

In addition to the problem of supply, 3-D cameras have several operational disadvantages when compared with modern 35-mm slide cameras. These include built-in lenses that are not interchangeable, antiquated manual controls, and difficult focusing adjustments (particularly in low light settings). The first two shortcomings can be overcome by using the slide bar discussed in the next

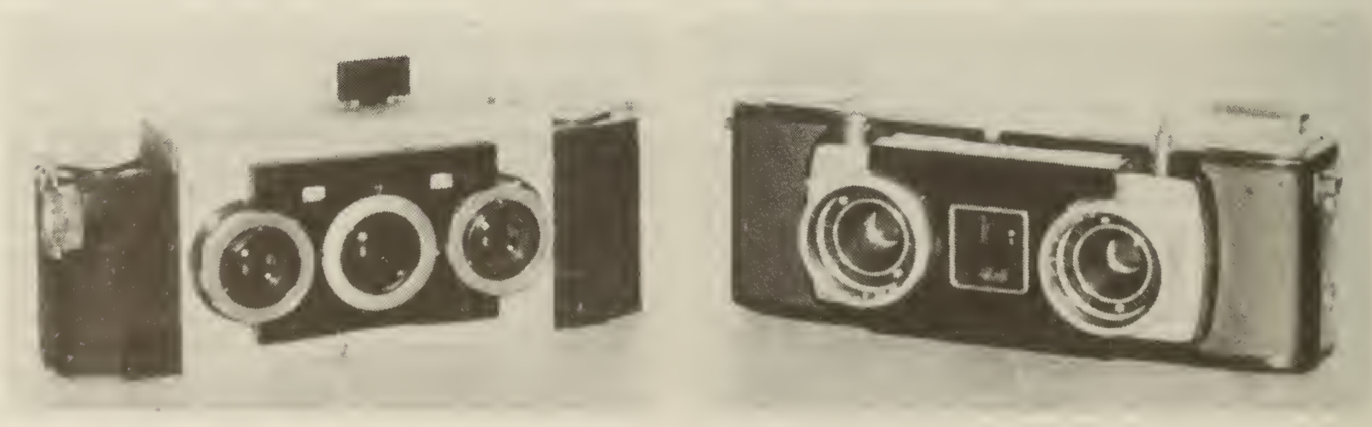

Figure 1.—3-D cameras.

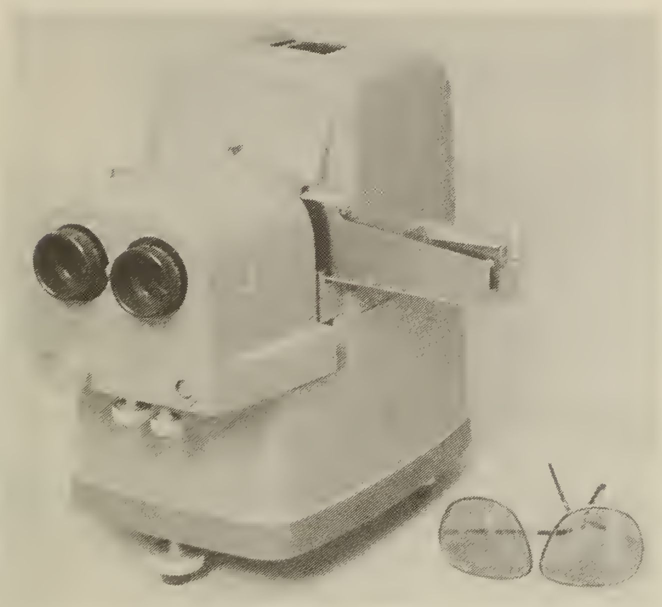

Figure 2.—3-D slide projector and 3-D glasses.

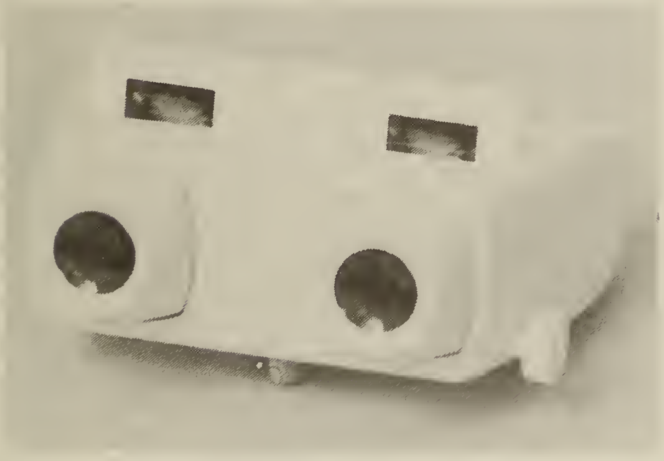

Figure 3.—Handheld 3-D slide viewer.

section. Setting the correct focus for a subject in the dim underground environment can be accomplished by using the distance, f-stop linear calibrations indicated on the strobe light.

STEREOSCOPIC CAMERA SLIDE BAR

In order to surmount these 3-D camera problems and also to simplify the procedures for generating 3-D slides, the Bureau designed and fabricated a slide bar for producing 3-D slides using available photographic equipment. The stereoscopic camera slide bar (*6*) uses just one 35-mm, single lens reflex camera to take matched pairs of individual slides (left slide and right slide) from two preset

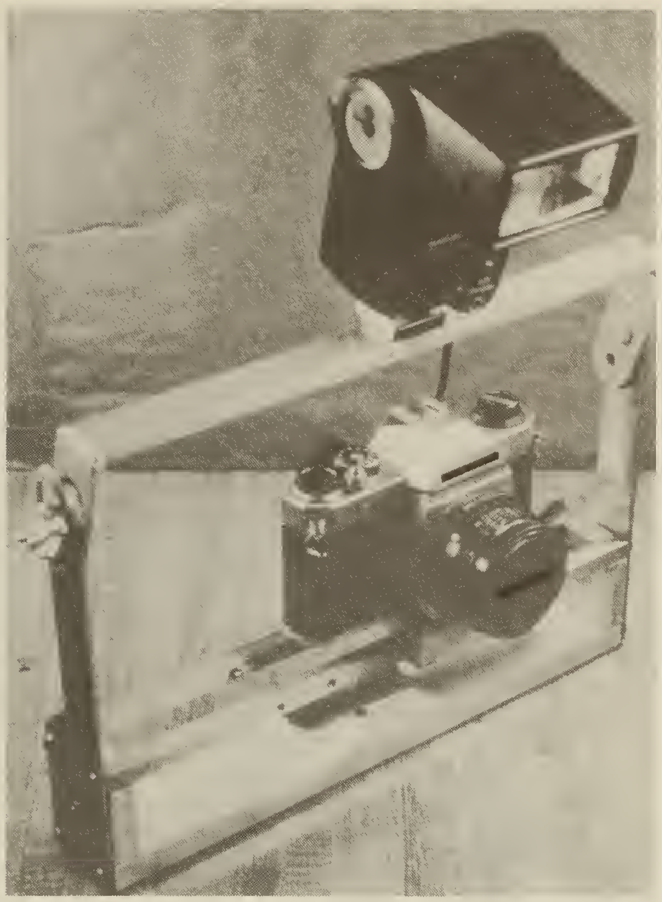

Figure 4.—Slide bar for taking 3-D slides with standard 35-mm camera.

locations (fig. 4). These positions correspond to the interocular distance between lenses, 2.75 in, used on the original, dual lens 3-D cameras. The unit basically consists of three horizontal bars situated one above the other. The lower bar is used for mounting the unit on a tripod and for holding a simple line level. The middle bar holds the camera, which is attached to a track-mounted sliding plate, and the upper bar supports the strobe light that is secured at a location central to each of the two camera positions. Detailed design drawings for construction of the slide bar are included in the appendix. The bar can be constructed of aluminum or steel stock and contains no parts that are unusually difficult to cut. The complete device can be fabricated and assembled in-house and requires no particular skills other than those typically found among workers in a mine repair shop. Description of the slide bar operation follows.

The bar, attached to a standard tripod for stability, is balanced horizontally using the line level. The left slide is then taken after the camera is moved to the leftmost position on the middle bar. A strobe light, mounted on the top bar and connected to the camera via a shutter cord, is

fired from its fixed location. After "sliding" the camera to the rightmost position on the bar, the right slide is taken. The strobe light is again fired from the same fixed position, insuring that shadows in each slide are identical and balanced. After taking a pair of slides, a blank slide is included in the sequence before taking the next set; this eliminates confusion during the slide assembly process.

An important feature available when using the stereoscopic camera slide bar is the opportunity to change camera lenses to suit the occasion. Original 3-D cameras have built-in, fixed lenses that are not removable. Thus, by using either a zoom lens, a telephoto lens, or a wide angle lens, the subject in the 3-D slide can be captured from a range of distances and directions without moving the tripod and camera from its original position. This is an efficient method for generating multiple slides of a particular hazard, where each slide can represent a different field condition such as variable lighting, multiple shadows, projection from roof or rib, etc. Safety is also a consideration here. It is much safer for the photographer to film a closeup view of a hazardous roof condition using a zoom lens from a secure distance of perhaps 30 ft than assuming a position near to the danger area.

ASSEMBLING AND VIEWING 3-D SLIDES

The matched 35-mm slide pairs can either be projected on a screen or mounted and observed in handheld viewers. To project the slide pairs on a screen (lenticular type only), two conventional slide projectors can be positioned vertically and the lenses angled slightly so the images overlap on the screen (fig. 5). The lenses used in each projector should be similar and have polarizing filters (No. 7945 are acceptable) on each lens (fig. 6). If handheld viewers are used, then the individual 35-mm film chips must be mounted in aluminum stereo slide holders and cardboard stereo mounts (fig. 7). Both of these items are available in photographic supply stores. The mounting process, which follows, is quite basic and can be accomplished by a novice.

The film chips are placed in the aluminum holder so the left chip has slightly more subject exposed on the left edge of the slide; conversely, the right chip should show slightly more subject on the right edge. The holders are manufactured so that a fair amount of sideways adjustment is possible. In a trial and error process, the slides are alternately adjusted and viewed until the proper stereo balance is achieved. It will be obvious to the observer when the proper stereo position of the chips has been reached because the image will show depth and be clear throughout.

COST AND AVAILABILITY OF 3-D EQUIPMENT

The list of equipment in table 2 includes items that may be used to set up a 3-D slide training program, in-house. The costs are presented merely as a guideline; obviously they will vary, depending on quality, quantity, sizes, and sources. Standard items such as a 35-mm camera, conventional slide projectors, strobe light, and shutter cord are not noted.

TABLE 2. - Approximate costs and sources of 3-D equipment

Item	Cost	Source
3-D camera	$250	Camera stores; mail order.
3-D projector	550	Do.
Lenticular screen	110	Camera stores.
3-D glasses	5	Do.
Handheld viewer	20	Do.
3-D slide bar	NAp	Not commercially available.
Stereo slide holders and mounts.[1]	7	Camera stores.
Polarizing filter	13	Do.

NAp Not applicable. [1]Box of 50.

EQUIPMENT RECOMMENDATIONS

The most practical approach for training departments to set up a 3-D slide program is to acquire the items needed for producing 3-D slides using the slide bar. This represents the most advantageous direction because most materials necessary for startup are available either in-house or from camera shops, and the slide bar can be made in a local machine or mine repair shop.

A complete inventory would include the following items: slide bar, 35-mm camera, stereo mounts, handheld viewers, 35-mm slide projectors, lenticular screen, and 3-D glasses. The last three items can be excluded if handheld viewers are chosen at the mode of presentation. This approach is suggested if the training classes are small, say fewer than 10 or 15 persons. For larger classes, projecting 3-D slides on a screen may be the most efficient mode of presentation. In either case, original 3-D cameras are not recommended for producing the set of slides. The quality of stereo slides using the slide bar is far superior to those taken with a 3-D camera, primarily because of the lens interchange feature. For this reason, as well as for that of equipment availability, the slide bar offers greater flexibility for developing, in-house, a 3-D slide training program.

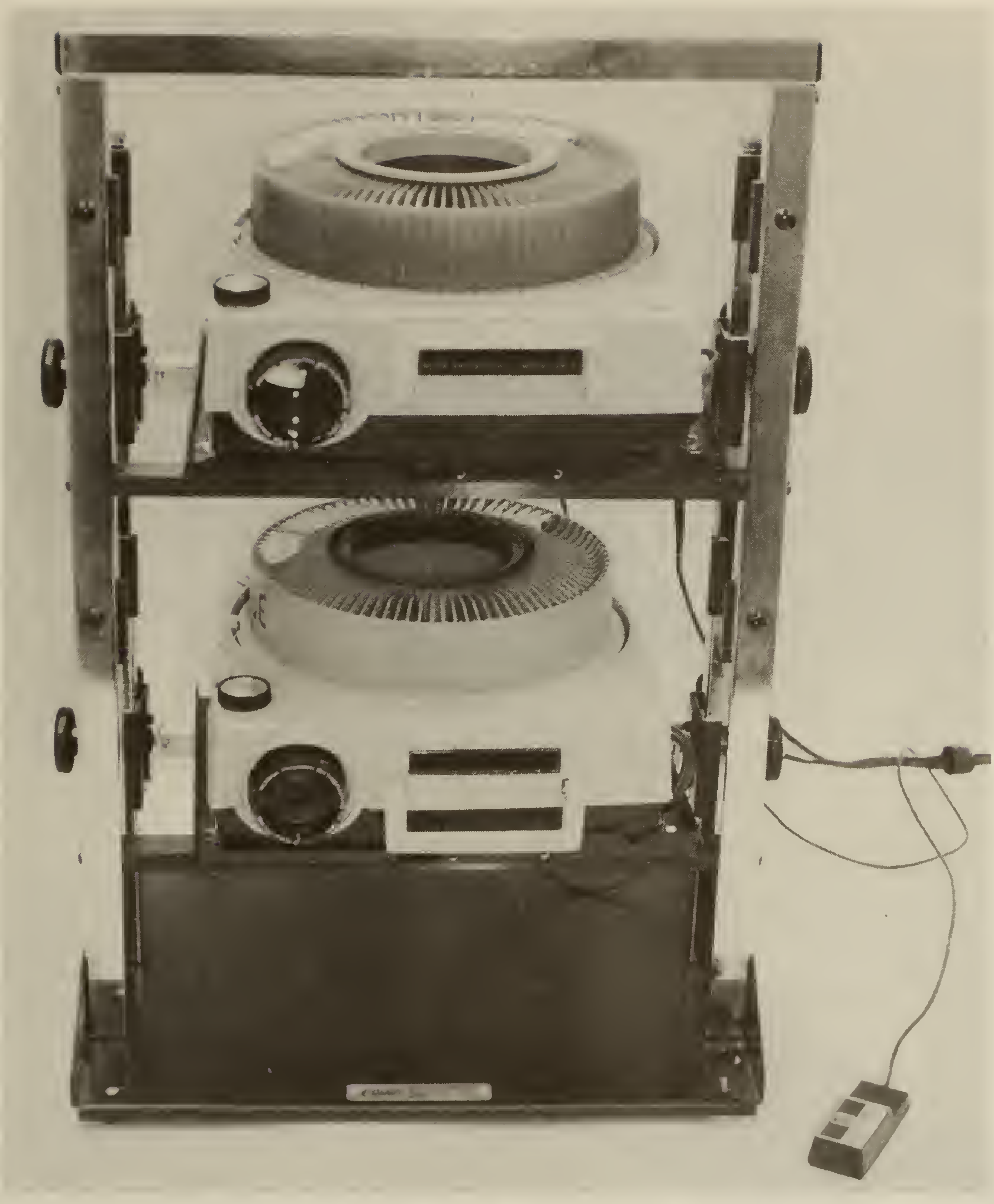

Figure 5.—Slide projectors vertically positioned on a two-tier shelf.

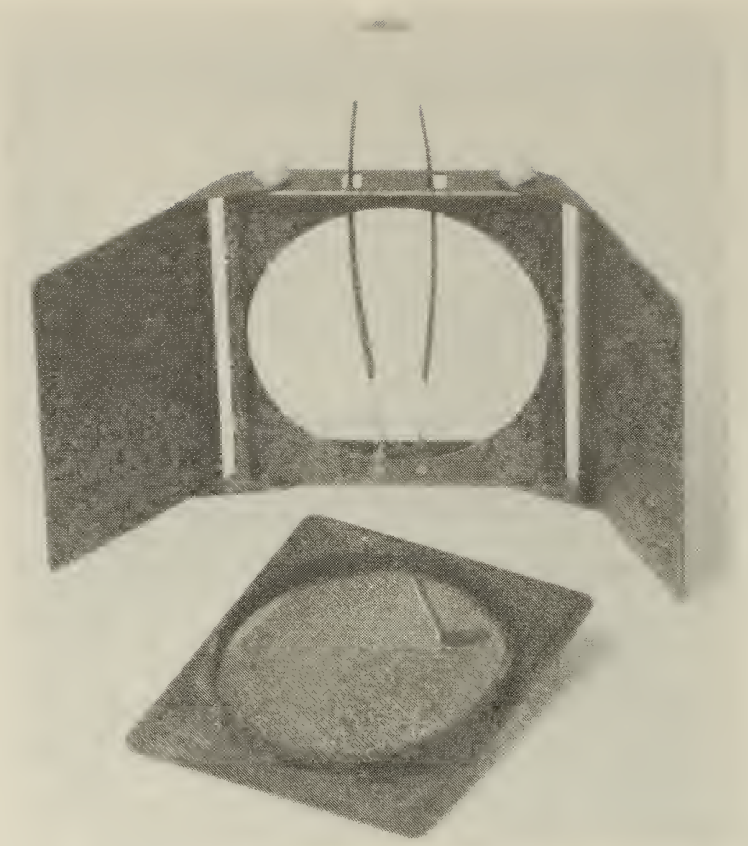

Figure 6.—Polarizing filter and filter holder.

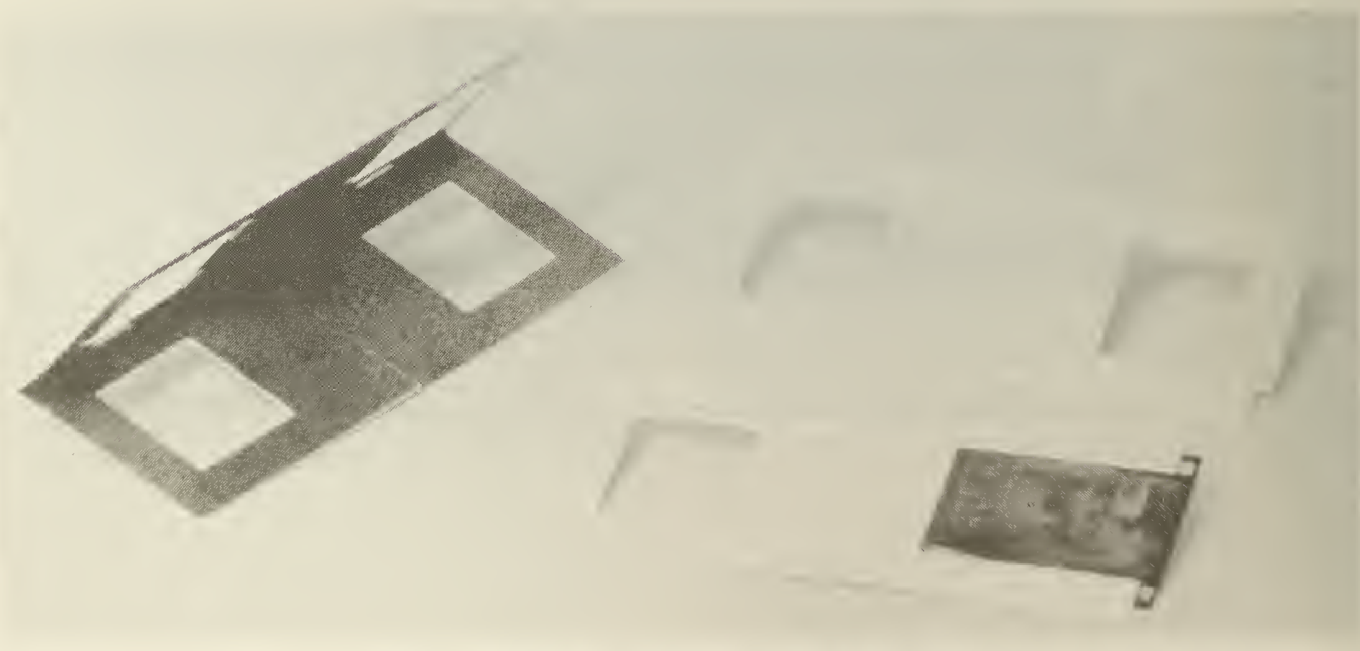

Figure 7.—Aluminum 3-D slide holder and cardboard mount.

RECOMMENDATIONS FOR TRAINING USING 3-D SLIDES

Because of the inherent advantage of 3-D slides, that is, to represent with impressive vividness the length, width, and depth of objects, they are a potentially valuable training aid for teaching hazard recognition skills in the classroom. Stereo slides offer a high-fidelity medium for representing real mine conditions.

There are several instructional advantages for advocating 3-D slides as a training aid. One major advantage for using 3-D slides in training is they ostensibly take the trainee into the mine without ever leaving the classroom. This is particularly important for ground control training. Providing instruction in the recognition of roof and rib hazards in an on-the-job mode is not always practical, efficient, or complete. Moreover, teaching hazard recognition on-the-job carries certain risks, particularly when the penalty for error may be extremely high.

A dilemma here is that many hazards may never get taught simply because they do not exist underground at the time of training, or, if they do exist, their nature or stage of development may vary from that under study. For example, cutter roof will initially appear as short separations in the mine roof running in the direction of the opening along the rib line. Eventually, they will develop into much longer separations that run on both sides of the entry for extended distances. Finally, an entire area affected by cutter roof will fail in shear and collapse at, or above, the roof bolt anchorage horizon level, unless appropriate support is installed. It is unlikely that all stages of this hazard would be represented in any mine at one given time. By using 3-D slides to depict each of several development phases of cutter roof, the trainee can be taught to recognize and assess this hazardous condition and subsequently make informed decisions on corrective actions to take at an appropriate time.

Another instructional advantage for using 3-D slides is that because of the availability of photographic equipment and the simple procedures for making slides, a 3-D ground control training program can be assembled and continually updated to meet training objectives by in-house personnel. This is particularly attractive to mine trainers because they can generate customized sets of 3-D slides that depict ground hazard conditions found in their own mine, perhaps even on the current working section, and do so with a minimum investment of company resources. Moreover, these customized slides create additional interest among trainees as they view familiar surroundings and, consequently, become more actively involved in training class discussions and more motivated to learn.

Stereoscopic slides can also play an important role in assessing or quantifying the visual skill levels of miners prior to training. By determining the capability of each worker in recognizing ground hazards initially, training can thus become more meaningful and efficient. In addition, learning outcomes of training and subsequent retention can be easily measured and evaluated. The ability of miners to perceive roof and rib hazards can be ascertained by using a representative set of 3-D slides that depict ground hazards found in their mine. Training that follows could be selective, that is, it would address those deficiencies diagnosed during the pretraining exercise. This, in effect, would establish a knowledge base for each person and a point of departure for subsequent training efforts.

A final comment on the use of 3-D slides for training relates to an often overlooked segment of most training programs, that of reinforcement of demonstrated safe conditions. Positive reinforcement can serve as an effective mechanism for enhancing any subject lesson. Stereo slides may be used to accomplish this objective by displaying 3-D scenes that contain no hazards; in other words scenes showing proper support, adequate scaling, uniform pillar corners with minimum sloughing, etc. These would serve to reinforce acceptable roof and rib conditions having proper support techniques. The high fidelity of 3-D slides in approximating the underground environment makes them quite suitable for this purpose.

SUMMARY

Miners possess varying degrees of hazard recognition skills that have been acquired through job experiences and training. Evidence exists that miners sometimes fail to recognize areas of hazardous roof and rib. Stereoscopic slides offer a unique medium for teaching and evaluating these skills. They realistically portray the natural mine environment and provide excellent proxies for miners learning to recognize the visual cues that characterize unstable ground conditions.

There are several advantages for using 3-D slides instead of conventional visual aids for illustrating groundfall hazards to miners. Perhaps the most important one is that 3-D slides provide a more accurate representation of roof and rib hazards and, because of their realistic appearance, they are intrinsically interesting to trainees. Miners seem to take a great deal of interest in training that involves 3-D slides and seem to enjoy looking at this type of slide. Based on the attitudes of miners and mine trainers, it appears that 3-D slides would be very well received as a training aid to complement the regular training program.

The equipment needed to produce 3-D slides is relatively inexpensive, easy to obtain, and basic to operate. Any standard 35-mm, single lens reflex camera can be used for taking ordered pairs of slides. The procedures for

mounting these pairs of film chips in 3-D slides holders can be accomplished by a novice with a minimum amount of practice. Most of the materials required for the complete 3-D process are available at photographic supply stores.

Some of the more important characteristics affecting the acceptance of any innovative mining technology by the industry are simplicity, availability, and cost. To this end, the Bureau has advanced and adapted the state-of-the-art of 3-D photographic equipment and procedures for documenting roof and rib hazards to the level that many mine training departments can inexpensively provide and maintain their own materials. Information presented in this report suggests that it is both feasible and advisable for trainers to use 3-D slides of hazardous roof and rib as a training aid for improving the miner's ability to recognize potentially dangerous ground conditions.

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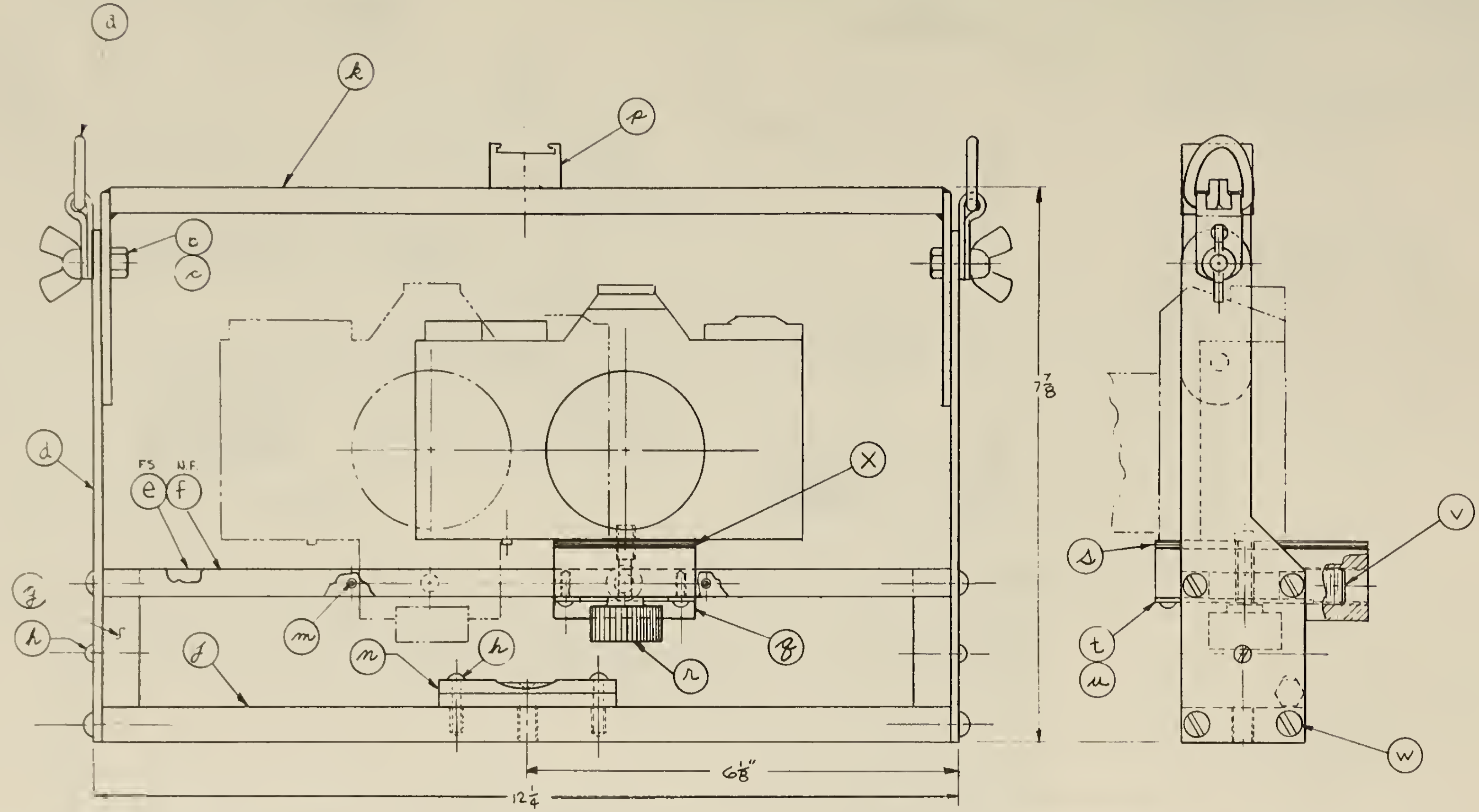
APPENDIX A.–DESIGN DRAWINGS FOR STEREOSCOPIC CAMERA SLIDE BAR



ITEM	QTY	NAME	DESCRIPTION	MATERIAL
a	2	LOOPS	1" 2 HOLE LOOP	STL
b	2	BOLTS	1/4-20 3/4 LG HEX HEAD	STL
c	2	WING NUT	1/4-20	STL
d	2	HANDLE	PL 5/8 x 1 3/4 x 7 1/4 LOW CARBON STL	A-36
e	1	RAIL	3/8 x 12 KEY STOCK	KEY STOCK
f	1	RAIL	1/8" x 12 KEY STOCK	KEY STOCK
g	2	SHEAR PLATE	PL 1/2 x 1 3/4 x 2" ALUM	ALUM
h	4	SCREW	6-32 3/8 LG CAP HEAD	STL
j	1	BASE	PL 1/2 x 1 1/4 x 12" ALUM	ALUM
k	1	FLASH ASSY	SEE SH THIS DWG	—
m	2	ROLL PIN	1/8 x 1/2 LG STL	STL
n	1	LEVEL	MOD LINE LEVEL	—

ITEM	QTY	NAME	DESCRIPTION	MATERIAL
p	1	FLASH MTG PLATE		
q	1	CAMERA MTG PLATE	BAR 1" x 2" x 5" LOW CARBON STL	A-36
r	1	CAMERA MTG SCREW	BAR 1" DIA x 1 3/4" LOW CARBON STL	A-36
s	1	MTG PAD	1/8 x 2" x 3" RUBBER	—
t	2	KEEPER PLATE	PL 1/16 x 1/2 x 2 3/16	A-36
u	2	SCREW	6-32 3/8 LG CAP HEAD SCREW	
v	1	PLUNGER	VLIER SSBL-60N 1/2-13 OR EQUAL	
w	8	SCREW	10-24 3/4 LG HEX SOCKET	
x	1	PAD	1/8 THK RUBBER MAT	

MK-1 BRACKET ASSEMBLY

DWG PREPARED BY BOEING SERVICES INT.

U.S. BUREAU OF MINES

ASSEMBLY — SCALE 1"=1" — DRAWN BY MOLCHEN — REVISED

STEREO/35MM CAMERA & FLASH BRACKET

DATE 12/6/85 — APPROVED BY — DRAWING NUMBER 851202 SH 1 OF 3

Figure A-1.–Stereoscopic camera slide bar assembly.

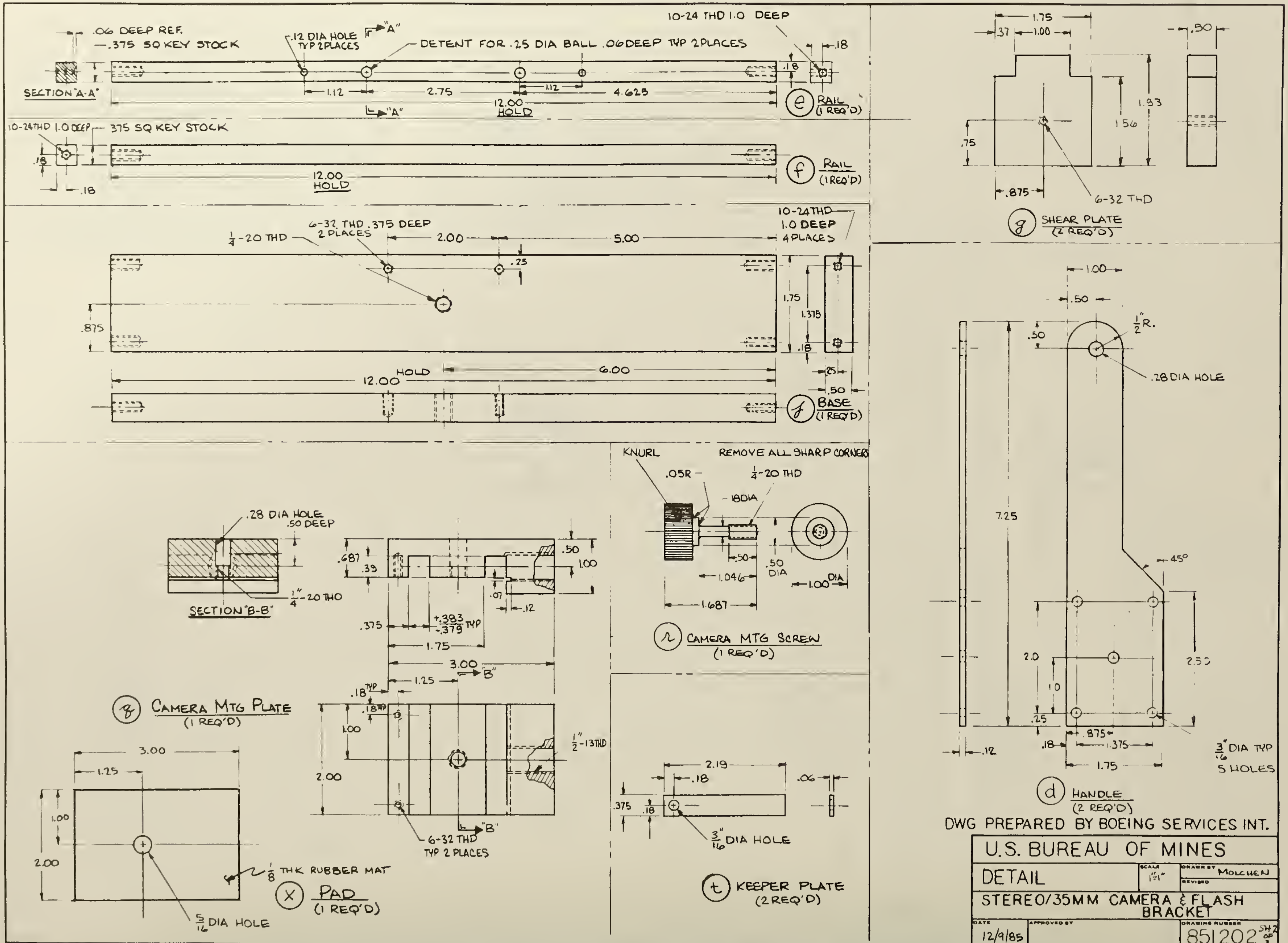


Figure A-2.—Stereoscopic camera slide bar detail.

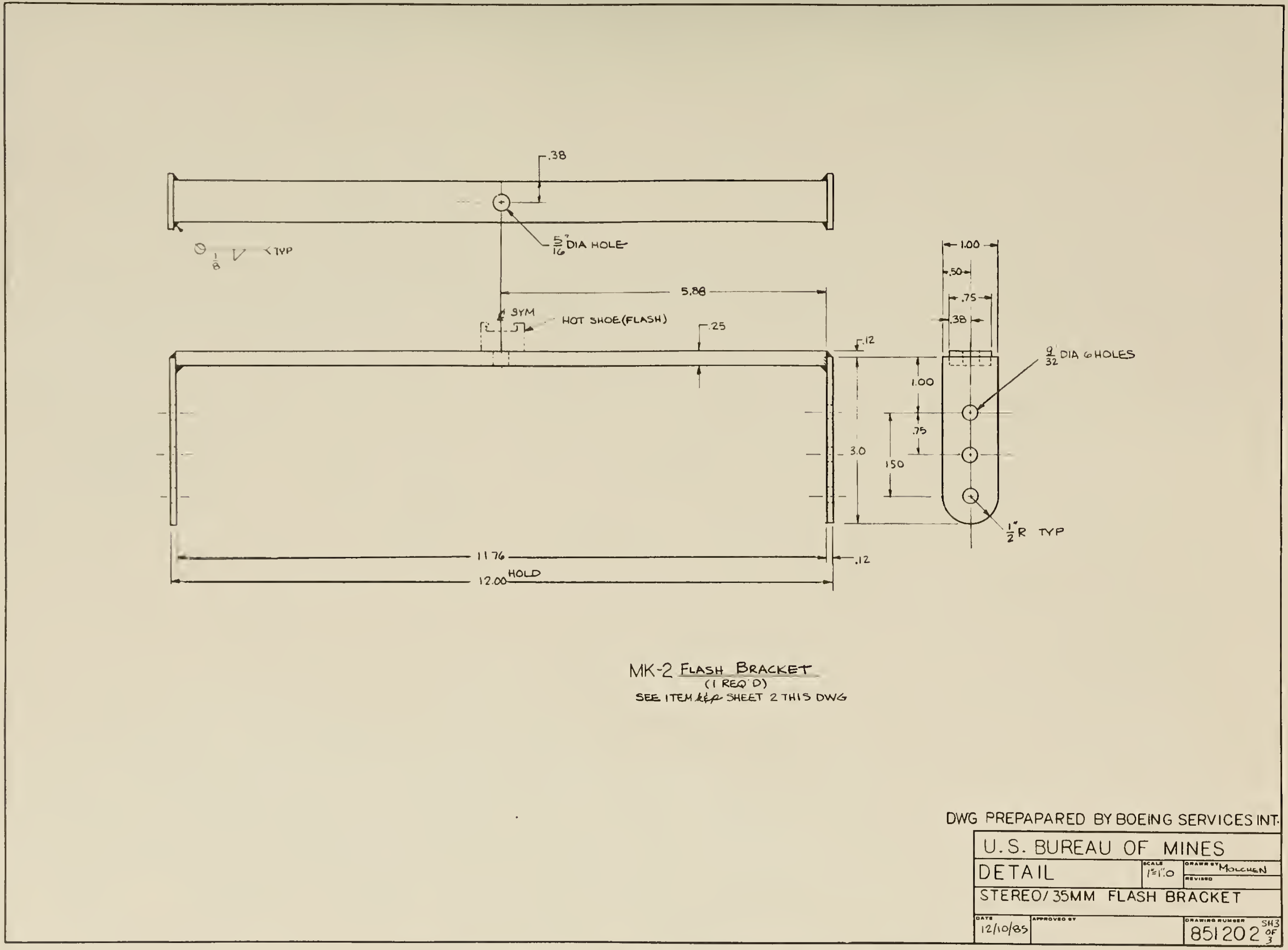


Figure A-3.—Stereoscopic camera slide bar flash bracket detail.

U.S. Department of the Interior
Bureau of Mines
Production & Distribution
Cochrans Mill Road
P.O. Box 18070
Pittsburgh, PA 15236